PREDICTION OF CUTTING POWER IN END-MILLING OPERATION OF MODIFIED AISI P20 TOOL STEEL

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

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To my Beloved Family:

PUAN SAODAH BINTI BADELI
ENCIK ABU BIN SARNI
NORHALIZAH BINTI ABU
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ERWINA NURSYAHEERA BINTI SULAIMAN

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ABSTRACT

The present paper discusses the development of the first and second order models for predicting the cutting power produced in end-milling operation of modified AISI P20 tool steel. The first and second order cutting force equations are developed using the response surface methodology (RSM) to study the effect of four input cutting parameters which is cutting speed, feed rate, radial depth and axial depth of cut on cutting power. The cutting power contours with respect to input parameters are presented and the predictive models analyses are performed with the aid of the statistical software package Minitab. The separate affect of individual input factors and the interaction between these factors are also investigated in this study. In first order model, the increase in the cutting speed, feed rate, axial and radial depths of cut will cause the cutting power to become larger. The received second order equation shows, based on the variance analysis, that the cutting power decreased when cutting speed, federate, axial and radial depth of cut is reduced. The predictive models in this study are believed to produce values of the longitudinal component of the cutting power close to those readings recorded experimentally with a 95% confident interval.

ABSTRAK

Kertas projek ini membincangkan perkembangan dalam pertama dan kedua susunan model untuk menjangkakan kekuatan pemotongan yang dihasilkan dalam operasi hujung kisaran terhadap modifikasi AISI P20 alatan besi. Persamaan pertama dan kedua susunan kekuatan pemotongan telah dikembangkan dengan menggunakan kaedah tindakbalas permukaan untuk mempelajari kesan terhadap empat pengeluar kekuatan pemotongan di mana ianya adalah kelajuan pemotongan, kadar pembekal, kedalaman axial dan radial terhadap kekuatan pemotongan. Kecerunan kekuatan pemotongan yang berkait dengan parameter pengeluar telah dibentangkan dan jangkaan model yang dianalisis telah dilakukan dengan bantuan perisian statistik Minitab. Pembahagian kesan terhadap individu faktor pengeluar dan interaksi antara factor-faktor ini juga telah disiasat dalam kertas projek ini. Dalam susunan model pertama, peningkatan kelajuan pemotongan, kadar pembekal, kedalaman axial dan radial terhadap kekuatan pemotongan telah menyebabkan kekuatan pomotongan juga meningkat. Penerimaan persamaan susunan kedua berdasarkan perbezaan analisis di mana kekuatan pemotongan berkurangan apabila kelajuan pemotongan, kadar pembekal, kedalaman axial dan radial terhadap kekuatan pemotongan telah dikurangkan. Jangkaan model dalam kertas projek ini dipercayai dapat menghasilkan nilai komponen membujur terhadap kekuatan pemotongan menghampiri kepada bacaan yg direkodkan secara experimen dengan 95% jeda keyakinan.

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LIST OF SYMBOLS

Vc	Velocity vector
kC	Specific cutting force
FD	Thrust force
p	Cutting power response
cs	Cutting speed
fr	Federate
ad	Axial depth
rd	Radial depth
y	Cutting power experimental value
$\hat{y}$	Cutting power predicted value
β_0, β_1, β_2, β_3 and β_4	Model parameter
ε	Experimental error
Py	Power component
x_0	Dummy variable
x_1, x_2, x_3 and x_4	Cutting speed, feed rate, axial depth of cut and radial depth of cut substitute in cutting power model.

LIST OF ABBREVIATIONS

AISI	American Iron Steel Institute
ANOVA	Analysis of Variance
ASME	American Society Mechanical Engineer
BUE	Built Up Edge
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CVD	Chemical Vapor Deposition
CNC	Computer Numerical Control
DOE	Design of Experiment
HSS	High Speed Steel
ISO	International Standard Organization
NN	Neural Network
PVD	Physical Vapor Deposition
RSM	Response Surface Methodology

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The advances in technology and the recent industrial revolution have led to an increased use of highly automated machine tools, machining centre and coordinate measuring machines. These modern machine tools with their inherent accuracy and associated precision, capable of being driven by computers have been responsible for the recent 'industrial revolution' leading to flexible manufacturing systems and modem computer based manufacturing. Efforts to further improve and optimize machining times and costs by reliable estimation of performance features such as forces, power, tool-life, temperatures and surface finish is increasingly becoming important in modern manufacturing industry (V. Karri and H. Talhami, 1995). To accommodate modern resource-intensive high-performance applications, large-scale computing and storage platforms have grown at a rapid pace in a variety of domains ranging from research labs and academic groups to industry. The fast-growing power consumption of these platforms is a major concern due to its implications on the cost and efficiency of these platforms as well as the well-being of environment. Trends from such platforms suggest that the power consumption in high-performance computing platforms accounts for 1.2% of the overall electricity consumption in the United State. More alarmingly, if current practices for the design and operation of these platforms continue, their power consumption is projected to keep growing at 18% every year. These observations have spurred great interest among providers of high-end computing platforms to explore ways to dampen the growth rate of servers by doing better consolidation as workload conditions change, it may be desirable to pack hosted applications on to different subsets of racks/servers within the data center and turn off machines that are not needed (P. Bohrer, D. Cohn, E. Elnozahy, T. Keller, M. Kistler, C. Lefurgy, R. Rajamony, F. Rawson and E. V. Hensbergen, 2001). Another major concern for such large-scale computing platforms is the increase in power density of the servers which are reaching the limits of the power delivery and cooling infrastructure of these platforms, thereby affecting the reliability concerns of these platforms. This has been addressed in literature by reducing the peak power consumption both at the server level (W. Felter, K. Rajamani, T. Keller, and C. Rusu, 2005) as well as at the cluster level (P. Ranganathan, P. Leech, D. Irwin, and J. Chase, 2006). Power budget is typically enforced at different hierarchies of a data center and it specifies a cap on the power consumption of applications consolidated under that hierarchy. Such research would be useful to an energy-friendly operation and management of consolidated platforms in a variety of ways. First, it will facilitate the prediction and control of energy consumption in consolidated environments. Second, in combination with existing research on workload characterization and application modeling, it will facilitate meaningful trade-offs between energy costs and application performance. Finally, ongoing efforts to develop power benchmarks would also benefit from such characterization. Consolidation may occur at multiple spatial granularities, ranging from co-location of multiple applications on a single server to diversion of workloads to a subset of the server racks or rooms. Correspondingly, characterization of power consumption is desirable at each of these levels.

1.2 PROBLEM STATEMENT

The long-term average power consumption within a subsystem dictates the energy costs involved in operating it. The possibility of sustained power consumption above thresholds associated with fuses/circuit-breakers critically affects the safe operation of devices protected by these elements (P. Bohrer, D. Cohn, E. Elnozahy, T. Keller, M. Kistler, C. Lefurgy, R. Rajamony, F. Rawson, and E. V. Hensbergen, 2001). Characterizing the properties of power consumption within a given consolidation hierarchy results in problems that are significantly different from those encountered in characterizing performance and resource usage. As a motivate example, considering the comparison of power consumption for two different consolidation scenarios, each packing a pair of applications on the same server. The power consumptions compared of individual applications with that when they were co-located. Prediction of power consumption requires to accurately identifying these dependencies. Furthermore, the success of such prediction also depends on the methodology used to measure and characterize individual consumption. Consolidation further increases the power density of the servers, aggravating the reliability concerns of the facility. Literature has addressed the energy and reliability related concerns in a data center using the notion of power budgets (R. Raghavendra, P. Ranganathan, V. Talwar, Z. Wang, and X. Zhu, 2008).

1.3 OBJECTIVES

The objectives of this study is to develop prediction first and second mathematical model for cutting power using response surface methodology when milling AISI P20 tool steel and to investigate the relationship between cutting parameters which is cutting speed, federate, axial and radial depth of cut with cutting power.

1.4 LIMITATION

The develop models only can be used in the certain range; cutting speed between 100 to 180 m/min, feedrate between 0.1 to 0.2 mm/tooth, axial depth between 1 to 2 mm and radial depth between 2 to 5 mm.

1.5 THESIS OUTLINE

This thesis consists of five chapters. Chapter 1 will state the background study, problem statement, objective and limitation of study while chapter 2 consists of literature review. Then followed by chapter 3 regarding experiment setup and design of experiment. Chapter 4 clearly explains the analysis and result obtained during experiment and finally chapter 5 will conclude the whole thesis and some recommended for future planning.

CHAPTER 2

LITERATURE REVIEW

2.1 OBLIGUE CUTTING

One of the earliest studies of three-dimensional cutting was undertaken in which the mechanics of cutting were analyzed for both orthogonal and oblique cutting. Mechant developed an equation for the chip flow angle, which is defined as the angle between a line that is normal to the cutting edge and the direction of chip flow on the tool face (M.E. Mechant, 1944). The cutting action along the cutting lips can be interpreted as occurring within a series of oblique sections, in which the rake and inclination angles vary radially along each lip (Foldvick, A.K., U. Kristiansen and J. Kvoerness, 1995). Figure 2.1 below shows the model of oblique cutting.

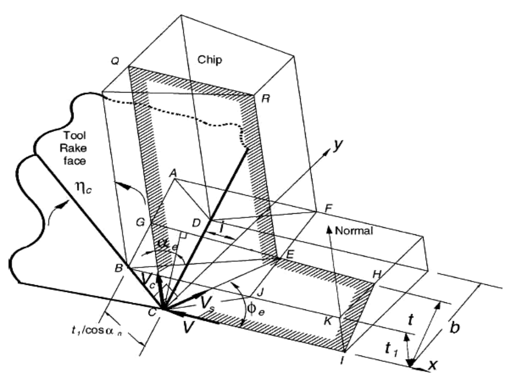

Figure 2.1: Model of oblique cutting

Source: J.S. Strenkowski, C.C. Hsieh and A.J. Shih (2004)

The three-dimensional cutting is interpreted as a series of orthogonal slices, each with the same effective shear plane angle and effective rake angle along the main cutting edge. In case of oblique cutting, which is practically more common, the actual direction of chip flow and the corresponding rake angle, effective rake should be used for more reasonably accurate analysis and assessment of cutting forces, friction and tool wear. An analytical model developed for predicting the chip flow angle and three-dimensional tool forces is first reviewed. The analysis is based on an energy approach in which three-dimensional cutting is approximated as a series of orthogonal slices. Using orthogonal cutting data under equivalent cutting conditions, the chip flow angle and three-dimensional tool forces can be determined for single-point tools with a nose radius (E. Usui and A. Hirota, 1978). An early attempt to predict three-dimensional cutting forces was also reported in which the forces were predicted from the workpiece flow stress measured in a machining test (G.C.I. Lin and P.L.B. Oxley, 1972).

2.2 CUTTING POWER

There have been many studies concerning the effect of cutting parameters and rake angle on the cutting forces. The influence of machining parameters such as cutting speed, feed rate, axial and radial depth of cut for different materials have been investigated (J.W. Youn, M.Y. Yang and H.Y. Park. 1994; A.J. Shih. 1996). The earliest model to describe the metal cutting process is based on the shear plane assumption of Ernst and Merchant (Ernst, H. and Merchant, M. E. 1941). Development a model for orthogonal cutting to predict forces and average temperatures and stresses in the deformation zones by using cutting conditions .Cutting forces are either measured in the real machining process or predicted in the machining process design. Cutting forces are measured by means of special device called tool force dynamometer mounted on the machine tool. More advanced options for cutting force prediction are based on analytical or numerical modeling of metal cutting. Due to the complex nature of the cutting process, the modeling is typically restricted to orthogonal cutting conditions, although solutions for the three-dimensional cutting are also available in the literature. The cutting force value is primarily affected by cutting conditions such as cutting speed, federate and depth of cut, cutting tool geometry such as tool orthogonal rake angle and properties of work material. In machining industries and research and development sections the cutting power are desired and required to be measured by experiments for determining the cutting power accurately, precisely and reliably unlike analytical method. It could also determining the magnitude of the cutting forces directly when equations are not available or adequate and to experimentally verify mathematical models. Otherwise, the purpose of measurement cutting power to explore and evaluate role or effects of variation of any parameters such as cutting speed, federate, axial and radial of depth, involved in machining, on cutting forces and friction which cannot be done analytically. It could also determine and study the shear or fracture strength of the work material under the various machining conditions and predict the cutting tool condition such as wear, chipping, fracturing and plastic deformation from the online measured cutting forces. Nevertheless, it could directly assess the relative performance of any new work material, tool geometry, cutting fluid application and special technique in respect of cutting forces and power consumption. Experimental evidence had shown that the dependence of the specific cutting energy on the chip thickness and cutting velocity can be well described by a power law relationship (Sabberwal, A. J. P. 1961; Oxley, P. L. B. 1963). The specific cutting energy decreased significantly with speed using relatively large negative rake angle tools (Davies, M. A., Chou, Y., and Evans, C. J. 1996).

2.3 DYNAMOMETER

Various dynamometer design techniques have been used in force measurement based on strain measurement and ring theory (M.C. Shaw. 1984; K.N. Strafford and J. Audy. 1997; M. Santochi, G. Dini, G. Tantussi and M. Beghini, 1997) mechanical force measurement device with three axis (N. Otmanboluk, I. Ay and Z. Aksoy. 1987), dynamometers with dial gage, piezoelectric dynamometer with three part (L.J. Plebani and J.J. Fu. 1993; A.J. Shih. 1996; W.L. Jin, P.K. Venuviod and X. Wang. 1995), sensor integrated into rotary tool (X. Dai and G.H. Gautschi. 1997; B. Yardimoglu and L. Boyar. 1992) and dynamometer included load cells based on strain measurement (J.W. Youn, M.Y. Yang and H.Y. Park. 1994). The existence of some physical variables like force and temperature and its magnitude or strength cannot be detected or quantified directly but can be so through their effects only. For example, a force which can neither